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NWC TP 5633

Warship Discrimination With Electro-Optical Sensors

by

Paul R. Decker

Weapons Development Department

APRIL 1974

Distribution limited to U.S. Government agencies only; test and evaluation, 19 March 1974. Other requests for this document must be referred to the Naval Weapons Center.

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Paul L. Pugh, RADM, USN . . . . Commander
Leroy Riggs . . . . Technical Director (Acting)

FOREWORD

An experiment on warship discrimination was conducted at the Naval Weapons Center, China Lake, Calif., between May and July 1973. This work was requested by the Naval Air Systems Command to determine the relationships between the various image quality parameters of electro-optical imaging systems and recognition/identification performance using these systems against ship- and land-based targets. The project was supported by AirTask No. A3400000/008B/4F55-525-401 under the direction of LCDR P. R. Chatelier (Code 340F).

This report was reviewed for technical accuracy by R. L. Sendall of Electro-Optical Systems, Pasadena, P. M. Moser of the Naval Air Development Center, Johnsville, Pa.; and Paul B. Homer and B. J. Gorrono, Naval Weapons Center.

Released by
GEORGE F. CLEARY, *Head*
Technical Services Division
1 April 1974

Under authority of
M. M. ROGERS, *Head (Acting)*
Weapons Development Department

NWC Technical Publication 5633

Published by . . . . Weapons Development Department
Manuscript 40/MS 74-5
Collation . . . . Cover, 23 leaves
First printing . . . . 170 unnumbered copies

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NWC TP 5633	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Warship Discrimination With Electro-Optical Sensors		5. TYPE OF REPORT & PERIOD COVERED Sensor Experiments May–July 1973
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Paul R. Decker		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Weapons Center China Lake, Ca. 93555		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62755N F55-525-401
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Weapons Center China Lake, Ca. 93555		12. REPORT DATE April 1974
		13. NUMBER OF PAGES 44
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to U.S. Government agencies only, test and evaluation; 19 March 1974. Other requests for this document must be referred to the Naval Weapons Center.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Modulation Transfer Function
Display Quality
Target Acquisition
Target Recognition
Target Identification
Electro-Optical Systems
Forward-Looking Infrared
Polarity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See back of form.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(U) *Warship Discrimination With Electro-Optical Sensors*, by Paul R. Decker. China Lake, Calif., Naval Weapons Center, April 1974. 44 pp. (NWC TP 5633, publication UNCLASSIFIED.)

(U) An experiment was conducted to investigate the effects of image size (range), image polarity, and modulation transfer function (MTF) on discrimination of warship targets with an electro-optical sensor. The imagery, which consisted of static warship silhouettes, was presented to subjects on a TV monitor in a controlled, laboratory environment.

(U) Image size was varied so that the target image lengths took on values of 15, 20, and 30% of the display width. MTF was varied over a relatively small range, with the best curve yielding a response of 0.5 at a spatial frequency of 15 cycles per display width and the poorest curve yielding only 0.23 at the same spatial frequency.

(U) Changes in image size caused the strongest effect, with performance at the largest image size averaging 57% higher than for the smallest image size. Correct identifications averaged 40% higher with the best MTF curve than with the worst. Performance against light targets on a gray background averaged 15% higher than for dark targets on the same background.

CONTENTS

INTRODUCTION

THE PROBLEM

There exists a great variety of electro-optical (E-O) imaging systems adaptable to airborne target acquisition applications. Most of the more sophisticated devices, notably the state-of-the-art forward-looking infrared (FLIR), were developed specifically for that purpose. Greatly increasing costs paralleled the rather rapid development of these extremely complex systems. These high costs, along with the keen competition that exists in this field, have necessitated the development and widespread use of a set of comprehensive, powerfully descriptive evaluation parameters and test procedures.[1] Modulation transfer function (MTF), minimum resolvable temperature (MRT), and signal transfer function (SiTF) are a few of the more commonly used parameters. With these evaluation tools, the prospective buyer can compare similar systems for performance versus cost optimization. However, this capability does not yet provide for predictable, task-dependent operator performance relatable to system cost.

During the late 1960s, a great deal of effort was put into increasing equipment performance and reliability. Lately, however, there has been a trend to place a greater emphasis on cost reduction, perhaps even at the sacrifice of performance. Therefore, it becomes extremely important that equipment performance, measured by MTF, MRT, SiTF, etc., be transformable into predictable levels of operator performance for specific tasks; i.e., target acquisition in a particular environment. Optimum operator performance is, after all, exactly what the prospective buyer needs at minimum cost. Unfortunately, the task-dependent relationships that exist between operator performance and equipment performance--and, hence, between operator performance and system cost--are not known.

This is the first experiment in a series intended to provide these required relationships in the basic area of electro-optically enhanced airborne target acquisition, primarily recognition and identification. It is expected that, when the planned series of investigations are completed, the data will be at hand to determine these relationships for a comprehensive set of equipment evaluation parameters. Then, and only then, will the E-O system user be able to confidently select equipment optimized for his application at the lowest possible cost.

[1] Institute for Defense Analysis. "A Guide for the Preparation of Specifications for Real-Time Thermal Imaging Systems," edited by L. M. Biberman. Arlington, Va., IDA, January 1971. (Paper P-676, publication UNCLASSIFIED.)

BACKGROUND

A complete description of imagery produced by typical E-O systems involves a set of parameters related to the raster sampling process, a set related to resolving capabilities in a direction along the displayed scan lines, and some parameters not related to basic resolving capabilities in either direction. Investigators in the past have mostly adhered to these divisions in their choices of independent variables. Variables related to the sampling process would include the number of scan lines across a target, scan line orientation, and scan line width. These variables have usually been investigated in combination with such parameters as target-to-background contrast, target image size, and signal-to-noise ratio.[2-5] A report by Fowler[6] describes an experiment in which the SiTF was varied. By comparison, there have been notably fewer investigations relating resolving capabilities along scan lines to human performance. There are quite a few parameters, some better than others, which describe a system's resolving capabilities in this case. These include electronic bandwidth, limiting resolution, and MTF. Limiting resolution, in the form of electronic bandwidth, was a variable in studies at North Carolina State University[7] and the Air Force Avionics Laboratory.[8] A few psychophysical investigations have been conducted

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[2] Naval Training Device Center. *Study, Perceptually Similar Visual Environment, Final Report*, by Barry C. King, Frank D. Fowler, and Richard P. Warner, Martin Marietta Corporation, Orlando, Fla., NTDC, December 1970. (NATRADEVCEN Tech Report 69-C-0188-1, publication UNCLASSIFIED.)

[3] Scott, Frank, Peter A. Hollanda, and Albert Harabedian. "The Informative Value of Sampled Images as a Function of the Number of Scans per Scene Object," PHOTOGR SCI ENG, Vol. 14, No. 1 (1970), pp. 21-27.

[4] Naval Weapons Center. *Image Identification on Television*, by Ronald A. Erickson and John C. Hemingway. China Lake, Calif., NWC, September 1970. (NWC TP 5025, publication UNCLASSIFIED.)

[5] Society for Information Display International Symposium. *1972 Digest of Technical Papers*. "Effects of Target Size, Target Contrast, Viewing Distance, and Scan Line Orientation on Dynamic Television Target Detection and Identification," by R. A. Bruns, A. C. Bittner, Jr., and R. C. Stevenson, Naval Missile Center. New York, Lewis Winner, June 1972. Pp. 148-149.

[6] Martin Marietta Corporation. *Target Acquisition Studies: (1) Two-Dimensional Compared With Three-Dimensional Targets; (2) Changes in Gamma for TV Displayed Targets*, by Frank D. Fowler, et al. Orlando, Fla., MMC, January 1971. (OR 11,091, publication UNCLASSIFIED.)

[7] North Carolina State University, Department of Electrical Engineering. *Information Processing Through Visual Perception as a Function of Signal-to-Noise on a Television Display*, by Dorothy Mae Johnston. Raleigh, N.C., NCSU, October 1971. (AD 732-311, publication UNCLASSIFIED.)

[8] Air Force Avionics Laboratory. *Low Light Level TV Viewfinder Simulation Program, Final Report* (U), by D. K. Bauerschmidt and J. M. Humes, North American Rockwell, Autonetics Division. Wright Patterson Air Force Base, Ohio, AFAL, February 1969. (AFAL-TR-68-363, publication CONFIDENTIAL.)

using the MTF or similar measures as independent variables. Two of these studies[9,10] have been conducted in search of a single summary measure of image quality. Rosell and Willson[11] reported on a summary measure approach involving the observer's spatial frequency-dependent signal-to-noise requirements.

Most investigators in this field have acknowledged the complex nature of human visual performance with E-O systems by reporting strong interactions between independent variables and large specific target dependences, pointing out a requirement for large-scale, multi-variate research. One continuing set of investigations[12] is uniquely similar to the study described in this report, both in selection of independent variables and of their levels. The main differences between the two studies are: (1) different target types, military vehicles versus warships; and (2) imagery generation techniques, digital processing of real infrared (IR) imagery by computer and presentation by photographic projection versus TV-simulated imagery put on videotape and presented in a cathode ray tube (CRT) display.

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[9] Office of Naval Research Target Acquisition Symposium. *A Collection of Unclassified Technical Papers on Target Acquisition, Vol. 1.* "A Unitary Measure of Video System Image Quality," by Harry L. Snyder, Virginia Polytechnic Institute. Prepared by Martin Marietta Corporation, Orlando, Fla., November 1972. (Report No. OA6201, Vol. 1, ONR Contract No. N00014-72-C-0389, publication UNCLASSIFIED.)

[10] Perkin-Elmer Corporation. "Search for a Summary Measure of Image Quality," by Frank Scott and Robert Hufnagel, presented as invited papers at the Annual Meeting of the Optical Society of America in Philadelphia, Pa., October 1965. Norwalk, Conn., P-EC, October 1965. (Paper UNCLASSIFIED.)

[11] Office of Naval Research Target Acquisition Symposium. *A Collection of Unclassified Technical Papers on Target Acquisition, Vol. 1.* "Signal-to-Noise Ratio Thresholds for Image Detection, Recognition, and Identification," by Frederick A. Rosell and Robert H. Willson, Westinghouse Defense and Electronic Systems Center, Baltimore, Md. Prepared by Martin Marietta Corporation, Orlando, Fla., November 1972. Report No. OA6201, Vol. 1, ONR Contract No. N00014-72-C-0389, publication UNCLASSIFIED.)

[12] Office of Naval Research Target Acquisition Symposium. *A Collection of Unclassified Technical Papers on Target Acquisition, Vol. 1.* "The Effect of Image Quality on Target Recognition," by Leon G. Williams and Carl P. Graf, Honeywell Research Labs. Prepared by Martin Marietta Corporation, Orlando, Fla., November 1972. (Report No. OA6201, Vol. 1, ONR Contract No. N00014-72-C-0389, publication UNCLASSIFIED.)

THE APPROACH

EXPERIMENTAL DESIGN

This study was conducted in two parts, referred to as Experiment I and Experiment II. In both experiments, the subjects were presented with TV-displayed silhouettes of warships. The independent variables in these random factorial experiments were image size (range), image polarity, and target-to-observer MTF. Each subject in Experiment I saw all possible combinations of target, image size, and MTF three times, with half the subjects receiving one polarity and the other half receiving the opposite polarity. Each subject in Experiment II twice saw all combinations of all variables, including polarity. There were three levels of both image size and MTF. The design is summarized in Figure 1. The task used as a performance measure was that of forced-choice identification with four possible targets. Photographs of the four ships are shown in Figure 2. Appendices A through J contain imagery photographs, confusion matrices of subjects' responses, performance curves, etc., relating to these experiments.

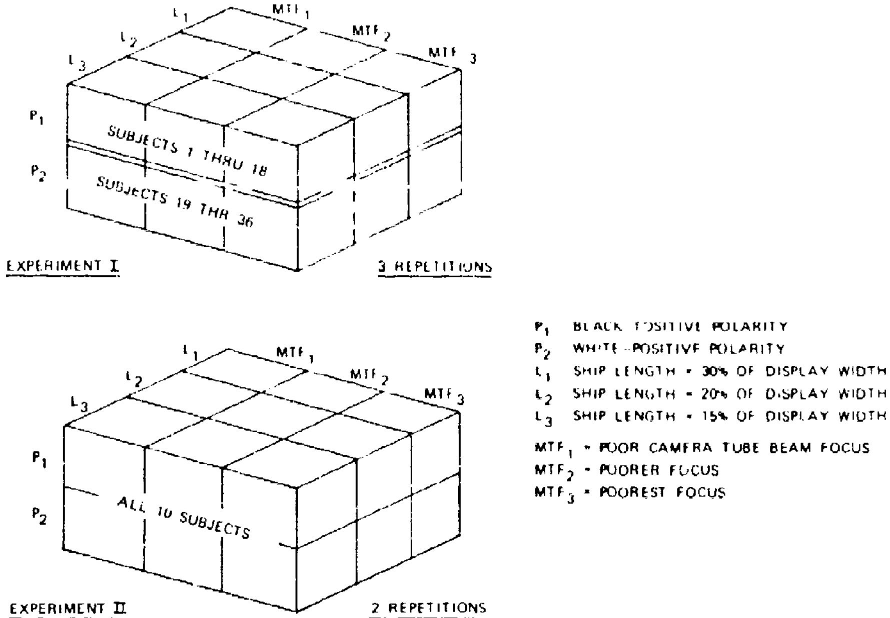
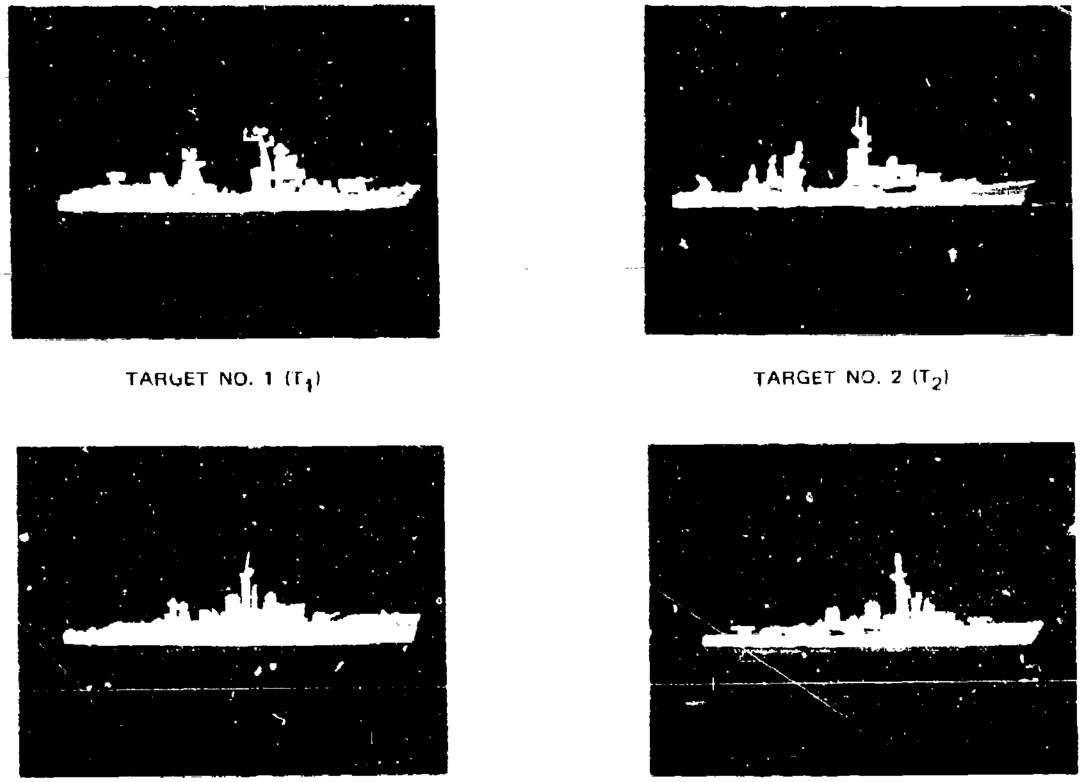


FIGURE 1. Experimental Design.



TARGET NO. 1 (T_1) TARGET NO. 2 (T_2)

TARGET NO. 3 (T_3) TARGET NO. 4 (T_4)

FIGURE 2. Photographs of 1:1200 Scale Models.

TEST PROCEDURES

Experiment 1

The subject sat in a darkened room in front of a 9-inch diagonal, standard 525-line TV monitor. The viewing distance was maintained at 24 inches. As the subject examined reference photographs on a briefing card, which was available throughout the experiment, he listened to a recording of the instructions given in Appendix F. After the instruction phase of the briefing, the subject participated in a series of practice trials, which consisted of one complete set of target/condition combinations; that is, four targets, three image sizes, and three MTF curves, resulting in a total of 36 trials. These trials were blocked in MTF to facilitate ease in video recording, and were presented in two sets, resulting in six blocks of six trials each. The target/image size combinations were randomly ordered in these trials. The actual order given each subject was the same and is shown in Appendix G.

Each practice trial of the first set began with a 10-sec static display of a ship silhouette, the appearance of which was simulataneous with a correct, audible identification of the ship. This 10-sec "look" was followed by a 5-sec pause, during which the TV monitor was blank. This set of practice trials, comprising 18 trials, was 4.5 min long. In the second set of 18 practice trials, a buzzer signaled the beginning of the 15-sec trials. Before the end of the 15-sec the subject was required to verbally identify the ship, as he would have to do in the main experiment. Then there was an additional 5-sec "look" in which the subject was told the correct choice, followed by another 5-sec pause preceding the next trial.

The briefing and practice trials were followed by a break of about 5 min before the beginning of the experimental trials. The procedure and method of presentation of the experimental trials were identical to those of the second set of practice trials. As before, the imagery was blocked in MTF, resulting in three blocks of 12 trials each, one trial for each combination of target and image size. The order of presentation within the blocks, as well as the blocks themselves, was randomized. Each subject was presented with three repetitions of the experimental trials, each repetition with a different randomized order of presentation. The only exception to complete randomization of the experimental trials was that the first block of each repetition was not allowed to be of the same MTF as that of the first block of any preceding repetition. Each repetition of 36 trials took about 9 min and there was a 2-min rest break between repetitions. The orders of presentation shown to each of the 36 subjects are given in Appendix G.

Experiment II

A second set of experimental trials was conducted to provide a better assessment of the polarity effect by eliminating the confounding between polarity and the two subject groups. This was done by recalling the subjects to retake the same experiment, but with the opposite polarity. Hence, for each subject the results from Experiment I were combined with the results of these additional trials and analyzed as Experiment II. Several days elapsed between Experiment I and the second set of trials. The presentation order was the same as before for each subject. Limited subject availability and an attempt to balance the experiment in terms of presentation order resulted in only 10 subjects taking part and their presentation orders are given in Appendix G. Each subject began this part of the experiment with no briefing and was presented with only the second set of practice trials from the videotape used in Experiment I. He also was presented with only the first two of the three taped experimental repetitions. Therefore, the results of these trials, along with the results of only the first two of the three Experiment I repetitions, comprise the data analyzed as Experiment II.

SUBJECTS

The subjects who participated in these experiments were all men who had been employed by the Naval Weapons Center for approximately 2 years or less. A list of these "new" employees was available and convenient for subject procurement. All subjects were between 20 and 30 years of age and were accepted to participate in the experiment by demonstrating binocular vision corrected to at least 20/20 on a Bausch and Lomb "Armed Forces Vision Tester." The subjects all indicated that they had never seen similar imagery before.

APPARATUS

The equipment components used for the recording and playback of the warship imagery, along with their main functions, are listed in Table 1. Simplified schematics of the recording and playback configurations are shown in Figures 3 and 4.

TABLE 1. Apparatus, Description and Function.

Equipment	Function
TV Camera System, Cohu 6000 Series with Westinghouse 8521 Vidicon	Generate test video imagery Provide polarity control Provide MTF control
Videotape Recorder, Ampex Model 660B	Record test imagery, verbal briefing, and buzzer signals Play back same to subjects
TV Monitor, Conrac Model RND9 with standard 9-inch diagonal display	Present test imagery to subjects Background luminance and image contrast control
Oscilloscope, Tektronix Model 7613 with TV Synch Separator and Plug-ins 7A18, 7B53A, and 7D11	Monitor video signal characteristics during taping Measure video signals during equipment characterization
Telephotometer, Gamma Model IC2000	Monitor background luminance and image contrast during experiment
Microphotometer, Gamma Model 700-10-50 with single slit analyzer	Measure system MTF and SiTF during equipment characterization

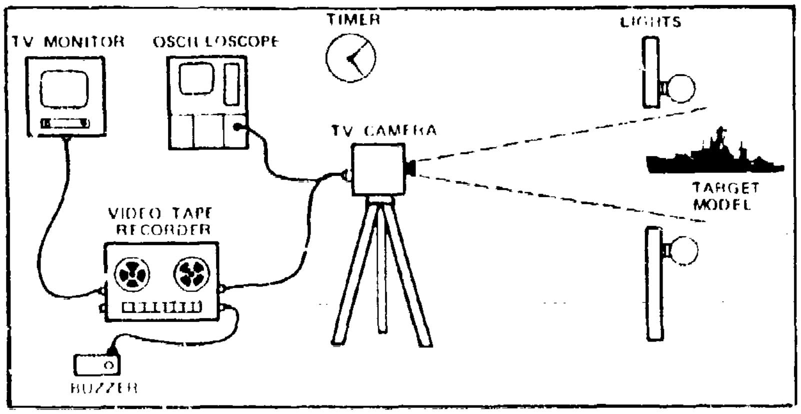


FIGURE 3. Imagery Recording Configuration.

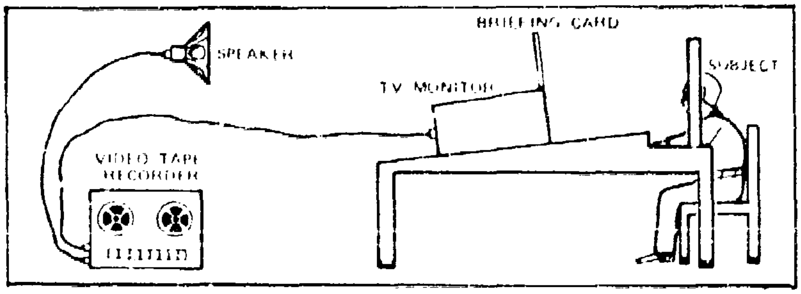


FIGURE 4. Experimental Playback Configuration.

IMAGERY DEFINITION AND EQUIPMENT PARAMETERS

The imagery used in the experiments can best be described in terms of the measurable operating parameters of the video equipment and the geometry of the taping and playback configurations. A detailed discussion of the method by which the values of image size and MTF were selected is given in Appendix J.

Image Size

Image size is defined in terms of the lengths of the ships' images as proportions of the active display width. Nominal values used in this experiment were 15, 20, and 30%, which were obtained by using three different target-to-camera distances during videotaping. These dimensions were equivalent to actual image lengths of 1.1, 1.4, and 2.2 inches on the 7.2-inch-wide TV monitor. A more precise description of the ships' lengths is given in Table 2. These image lengths were geometrically determined, i.e., only model size, viewing distance, display size, camera distance, and FOV were used. Table 3 provides two more descriptors of the size of the displayed images: the number of scan lines

comprising the target images and the angular subtense of the target images to the subjects' eyes. Calculation of these data was also based on the actual scale model lengths. The value of the MTF and the SiTF can affect the actual size of the displayed image and this is di cussed in Appendix I.

TABLE 2. Ship Image Lengths by Geometric Determination.[a]

Target No.	Nominal ship image lengths, % of active display width		
	15	20	30
1	15.2	20.3	30.5
2	15.0	20.0	30.0
3	15.0	20.0	30.0
4	14.5	19.3	28.9

[a] Well-focused.

TABLE 3. Scan Lines per Target Height and Angular Subtense to the Eye in Minutes of Arc[a]

Target	Target height, scan lines			Angular subtense, minutes of arc		
	Ship image length, % of display width					
	15	20	30	15	20	30
No. 1 	17	23	32	54	72	102
No. 2 	14	19	27	46	61	87
No. 3 	13	17	24	41	55	78
No. 4 	11	15	21	36	48	67

[a] Target heights are considered to be as shown by the dashed lines.

Modulation Transfer Function

The MTF of the system was controlled with the focus voltage of the standard, 1.5-inch vidicon camera tube. Direct measurements of the system's square-wave responses were made with square-wave bar patterns and a scanning microphotometer. Since the system's SiTF was reasonably linear, the sine wave responses (MTFs) were calculated[13] and are shown in Figure 5. Detailed discussions of the method employed, its disadvantages, and the resulting accuracy of the curves are given in Appendix I.

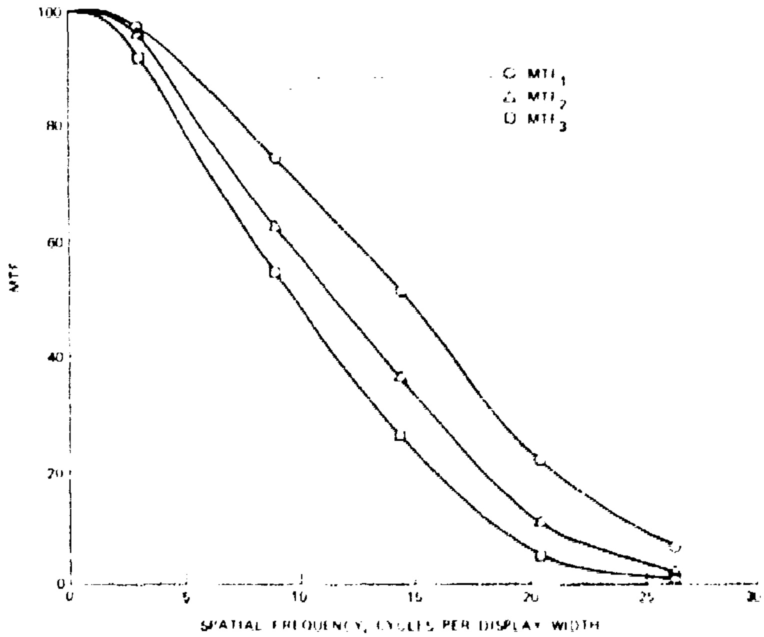


FIGURE 5. System Modulation Transfer Function.

Polarity

Polarity change was accomplished in the Cohu camera by reversing the output of the video amplifier and adjusting the blanking level to maintain calibration of the video signal levels. In the white-positive mode, the system displayed a light target on a darker, 5-foot-lambert

[13] Coltman, John W. "The Specification of Imaging Properties by Response to a Sine Wave Input," OPT SOC AMER, J. Vol. 44, No. 6 (1954).

background. In the black-positive mode, a darker target was displayed on the same gray background. In both cases, target/background contrast of *large* targets was 40% according to the definition

$$C = \frac{T - B}{B}$$

where T is target image luminance and B is background luminance.

Other Parameters

Additional equipment parameters and their values, as they were during taping and playback, are given in Table 4.

TABLE 4. Video Equipment, General Description.

Camera:	
Nominal line rate	525
Actual displayed scan line number	485
Video bandwidth	32 MHz
Interlace	2:1
Frame/field rates	30/60 per sec
Sync and blanking	EIA Spec. RS-330
Videotape recorder:	
General output specifications	FCC Std. 11A73-3678a(8)
Video bandwidth	3 MHz
Signal-to-noise ratio	40 dB
Display:	
Raster size	7.2 inches wide x 5.4 inches high
Phosphor type	P4
Raster line orientation	horizontal scan lines
Video bandwidth	10 MHz
DC restoration	100% sync tip clamp

DISCUSSION OF RESULTS

Subject performance ranged from 98% correct with the best combination of conditions to 11% with the poorest. Correct responses averaged 76% with the best MTF and 59% with the poorest, while the largest images yielded 86% correct and the smallest images yielded 48%.

Figure 6 shows the main effects of image size and MTF. Performance improved linearly with increasing size when the MTF was poor (MTF_3). However, with the best MTF, performance improved with image size at a rate comparable to the poorer curves only up to a "critical" size. For image lengths greater than about 20% of the display width, performance improved very little with increasing size. It would appear, then, that when the image lengths were 20% of the display width, the ships' features necessary for identification were detectable and for only slightly smaller images they were much less so.

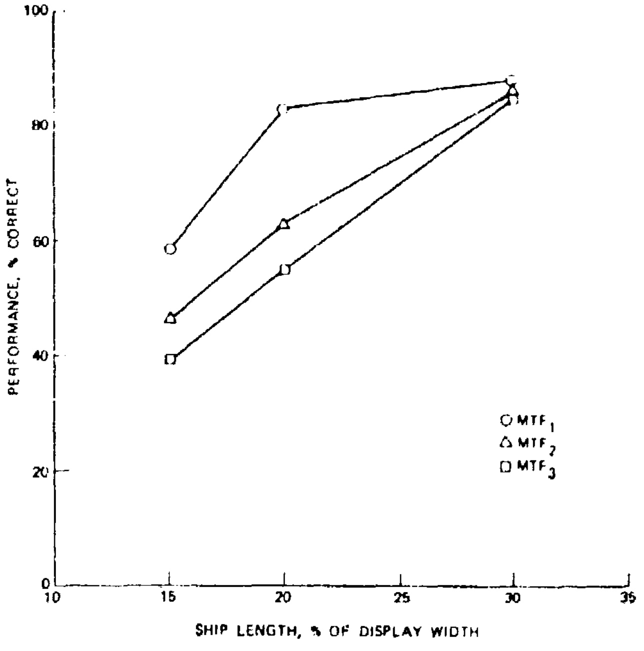


FIGURE 6. Performance Versus Image Size and MTF (Averaged Over Target and Polarity).

Figure 7 shows the effect of polarity on performance. Against light targets on a gray background (white-positive), the subjects averaged 73% correct, but only 63% against dark targets on the same background (black-positive). The polarity effect seems to increase as the image gets smaller and the MTF gets poorer. The data from Experiment II, which was conducted to separate subject group differences from the polarity effect, shows the polarity effect to be somewhat larger than in Experiment I at the smaller image sizes and at the poorest MTF (Figure 8). However, the practical significance of this effect seems to be small for the higher MTFs and larger images.

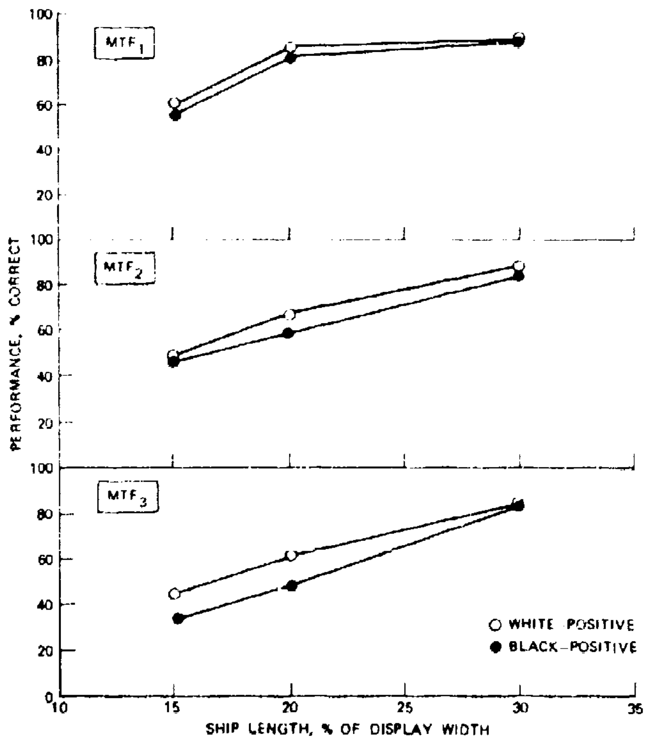


FIGURE 7. Polarity Effect, Experiment I.

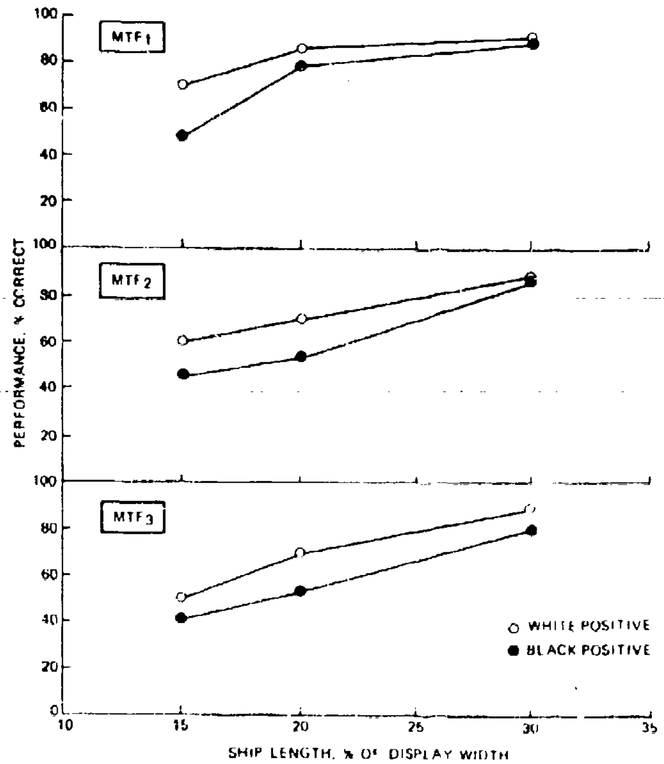


FIGURE 8. Polarity Effect, Experiment II.

The results also indicated a strong specific target effect and interactions between target and image size, as shown in Figure 9. The average performance against each target was as follows: No. 1, 70% correct; No. 2, 53%; No. 3, 78%; and No. 4, 68%. Table 5 gives the confusion matrix of the subjects' responses averaged over polarity. The on-diagonal entries in each block are the percentages of the responses that were correct and the off-diagonals are the percentages in error. It can be seen that the main target effect, indicated by differences between the diagonal entries, was relatively large with the poorer image qualities and much less apparent with the better images. Graphic representation of these data is given in Figure 10.

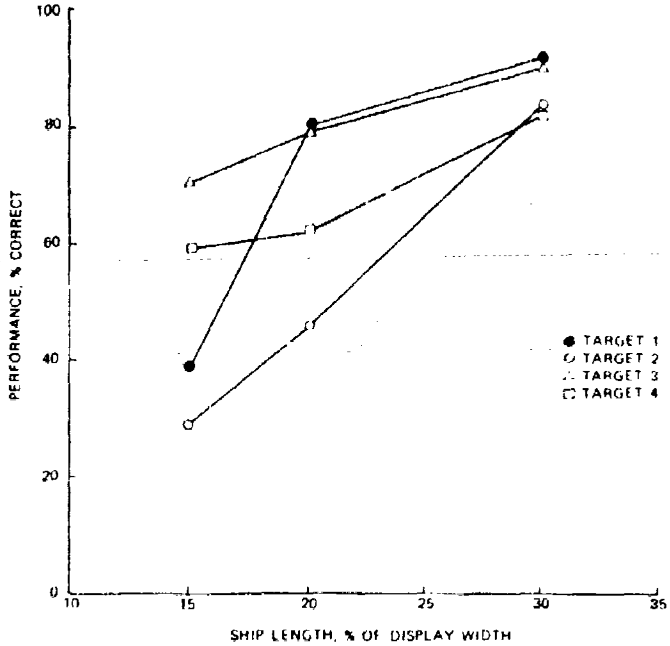


FIGURE 9. Target Effect (Averaged Over MTF and Polarity).

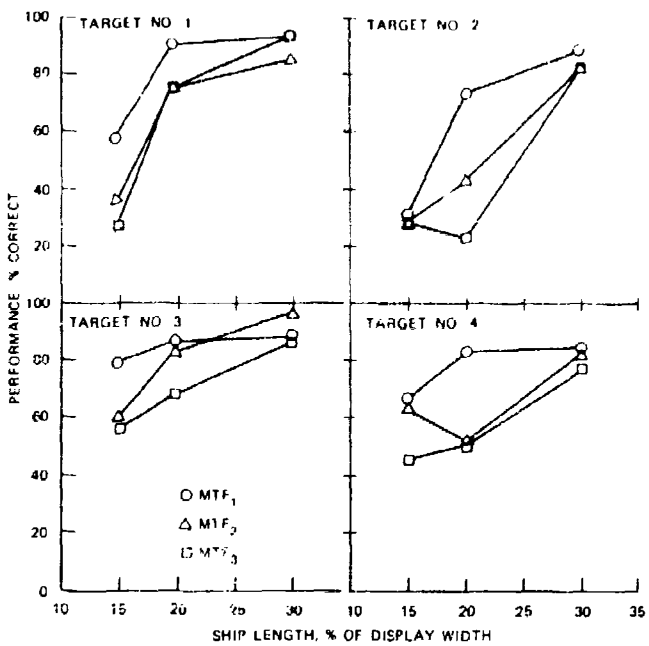


FIGURE 10. Image Size, MTF-Target Interactions.

TABLE 5. Confusion Matrix (Image Size and MTF).

Targets presented		Subjects' responses											
		Ship length, percent of display width											
		30%				20%				15%			
		1	2	3	4	1	2	3	4	1	2	3	4
MTF_1	1	93	8	–	–	90	5	2	4	57	14	19	11
	2	11	89	–	–	24	73	4	1	18	31	40	12
	3	2	12	87	1	5	5	86	4	5	9	79	8
	4	3	[illegible]	8	85	–	6	12	83	3	6	24	67
MTF_2	1	85	14	–	1	75	11	9	7	35	20	21	24
	2	19	82	–	–	35	42	12	11	10	28	33	28
	3	–	1	97	3	7	7	83	5	12	17	60	11
	4	3	2	13	83	9	13	25	52	1	10	22	63
MTF_3	1	94	5	–	1	76	12	9	3	26	19	19	34
	2	19	82	–	–	40	23	30	8	9	28	33	27
	3	5	5	86	6	13	10	68	10	7	20	56	17
	4	4	8	12	77	13	23	13	52	6	19	23	47

SUMMARY

In this forced-choice, image identification experiment subjects were presented with TV-displayed silhouettes of four warships. The ship images were presented one at a time, each time with a different combination of values of image size, MTF, and polarity. Target image lengths of 15, 20, and 30% of the active display width and three MTF curves ranging in sine-wave response from 0.5 to 0.23 at a spatial frequency of 15 cycles per display width were used.

The results indicate that there were strong individual target-dependent effects and significant two-way and even three-way interactions between main effects. With this caution on the interpretation of averaged data, the percent correct identifications ranged between 48 and 86 for the three levels of image size, between 59 and 76 for the three MTF curves, and between 53 and 78 for the specific targets. Performance averaged 63% correct for dark targets against a gray background and 73% for light targets against the same background.

APPENDIXES

Appendix A
PHOTOGRAPHS OF EXPERIMENTAL IMAGERY, ALL CONDITIONS

FIGURE A-3. Actual Black-Positive Imagery (L = Image Length, M = MTF).

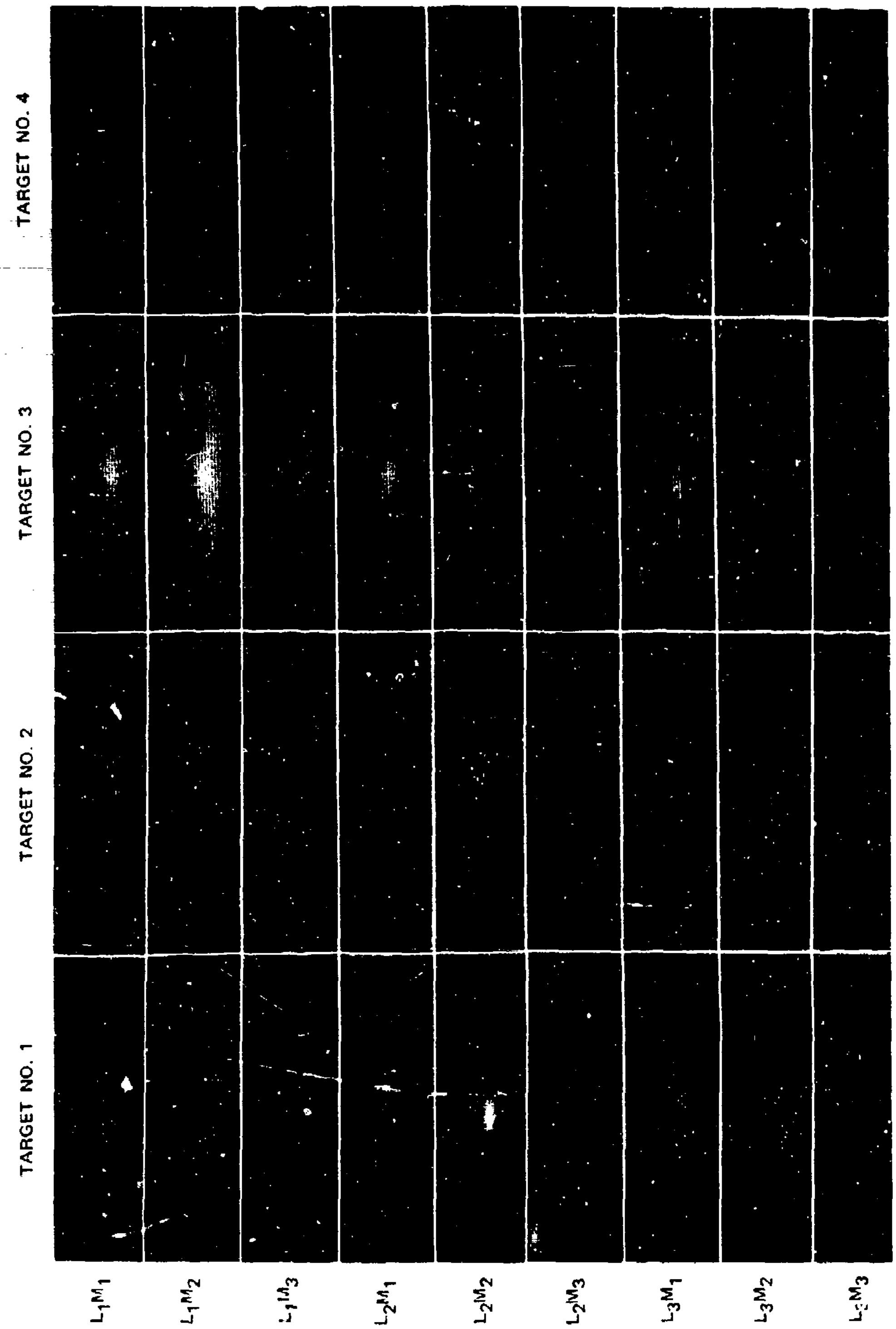


FIGURE A-4. Actual White-Positive Imagery (L = Image Length, M = MTF).

Appendix B

CONFUSION MATRICES: SUBJECTS' RESPONSES

TABLE B-1. Experiment 1. Confusion Matrices for Ship Discrimination With All Combinations of Image Size, MTF, and Polarity. (Numbers rounded off to nearest whole number.)

Targets presented			Image size											
			L_1 (30%)				L_2 (20%)				L_3 (15%)			
			Subjects' responses, %											
			1	2	3	4	1	2	3	4	1	2	3	4
Black-Positive	MTF_1	1	98	2	-	-	82	9	4	6	48	11	30	11
		2	13	87	-	-	15	76	7	2	15	29	37	20
		3	-	6	93	2	4	6	83	6	2	11	74	11
		4	6	9	11	74	-	6	13	82	4	9	13	74
	MTF_2	1	85	15	-	-	69	11	15	6	32	30	20	17
		2	17	83	-	-	20	37	22	20	-	33	22	43
		3	-	-	100	-	9	4	78	9	13	17	50	20
		4	6	4	24	67	11	19	22	48	-	13	20	65
	MTF_3	1	94	6	-	-	74	7	15	2	11	17	32	37
		2	13	87	-	-	24	13	54	9	2	24	28	41
		3	9	9	82	-	17	9	69	6	2	26	44	28
		4	6	9	13	72	19	22	22	37	4	11	24	52
White-Positive	MTF_1	1	87	13	-	-	98	-	-	2	65	17	7	11
		2	9	91	-	-	32	69	-	-	20	33	43	4
		3	4	17	80	-	6	4	89	2	7	6	83	4
		4	-	-	4	96	-	6	11	83	2	2	35	59
	MTF_2	1	85	13	-	2	80	11	2	7	37	9	22	30
		2	20	80	-	-	50	46	2	2	20	22	43	13
		3	-	2	93	6	4	9	87	-	11	17	70	2
		4	-	-	2	98	6	7	28	56	2	7	24	61
	MTF_3	1	94	4	-	2	78	17	2	4	41	20	6	30
		2	24	76	-	-	56	32	6	7	15	32	37	13
		3	-	-	89	11	9	11	67	13	11	15	67	6
		4	2	6	11	82	6	24	4	67	7	26	22	41

TABLE B-2. Experiment II. Confusion Matrices for Ship Discrimination With All Combinations of Image Size, MTF, and Polarity. (Numbers rounded off to nearest whole number.)

Targets presented			Image size: L_1 (30%)				L_2 (20%)				L_3 (15%)			
			Subjects' responses, %											
			1	2	3	4	1	2	3	4	1	2	3	4
Black-Positive	MTF_1	1	100	-	-	-	85	10	-	5	55	-	30	15
		2	10	90	-	-	50	50	-	-	5	10	60	25
		3	-	5	90	5	5	-	90	5	-	15	75	10
		4	-	20	10	70	5	-	5	90	-	10	40	50
	MTF_2	1	90	10	-	-	55	10	10	25	40	20	15	25
		2	20	80	-	-	25	30	30	15	-	35	35	30
		3	-	-	100	-	5	5	80	10	5	25	60	10
		4	10	-	15	75	15	30	10	45	-	10	45	45
	MTF_3	1	95	5	-	-	75	10	15	-	15	35	25	25
		2	35	65	-	-	10	15	55	20	5	20	30	45
		3	5	10	85	-	5	10	85	-	-	30	55	15
		4	10	5	10	75	20	25	20	35	5	10	10	75
White-Positive	MTF_1	1	90	10	-	-	95	5	-	-	75	-	15	10
		2	5	95	-	-	25	75	-	-	15	55	25	5
		3	15	10	75	-	5	-	95	-	5	5	90	-
		4	-	-	-	100	10	10	-	80	-	10	30	60
	MTF_2	1	80	20	-	-	90	-	-	10	25	10	35	30
		2	25	75	-	-	50	45	5	-	5	50	30	15
		3	-	-	95	5	5	5	90	-	5	5	85	5
		4	-	-	-	100	20	5	20	55	-	5	15	80
	MTF_3	1	90	10	-	-	85	10	-	5	55	20	5	20
		2	10	90	-	-	45	55	-	-	15	35	30	20
		3	-	-	95	5	10	10	65	15	15	15	65	5
		4	5	5	10	80	5	20	5	70	-	25	30	45

Appendix C

DETAILED SUMMARY OF ANALYSES OF VARIANCE

The basic data obtained from both phases of the experiment were subjected to analyses of variance: a four-way analysis for Experiment I and a five-way analysis for Experiment II.[14] The subjects in Experiment II saw both polarities, where one-half the subjects saw white-positive imagery first and the other half saw black-positive first. This provided for the five-way analysis in which the polarity effects were separated from any subject group differences.

These analyses are summarized in Tables C-1 and C-2. α is the fraction of the time that the differences in performance related to changes in a given variable or interaction between particular variables can be expected from only the statistical distribution of the data and not because of the variable changes or interactions themselves. ω^2 is an estimate of the amount of variance ascribed to changes in a given variable or interaction, given as a percentage of the total variance encountered in the experiment. These are totaled in the tables and it is interesting to note that the sum percentage of the total variance accounted for by this estimator was 43.4% in the four-way analysis, but only 4.7% in the five-way analysis. This should be explainable in terms of the two major differences in the data from the two experiments. The basic unit of data used in the analysis of variance was the number of correct responses per subject/target/MTF/image size/polarity combination. Therefore, in Experiment I, each data point in the analysis could have the value 0, 1, 2, or 3; whereas in Experiment II, only the values 0, 1, or 2 were possible. In addition, there were 36 subjects in Experiment I and only 10 in Experiment II.

[14] Winer, B. J. *Statistical Principles in Experimental Design.* New York, McGraw-Hill, 1962. Pp 248-257.

TABLE C-1. Summary of Analysis of Variance, Experiment I.

Source of variation	SS	df	MS	F	$\alpha^{\dagger}$	ω^2, %
Between subjects	88.89	35	← Totals →			0.5
P	9.68	1	9.68	4.15	0.05	0.5
error (p)	79.21	34	2.33			
Within subjects	1,335.06	1,260	← Totals →			42.9
L	289.43	2	144.72	185.54	0.01	21.5
PL	1.99	2	1.00	1.28		
error (l)	52.97	68	0.78			
M	58.47	2	29.24	63.57	0.01	4.3
PM	1.59	2	0.80	1.74		
error (m)	31.33	68	0.46			
T	94.83	3	31.61	37.19	0.01	6.9
PT	2.24	3	0.75	0.88		
error (t)	86.66	102	0.85			
LM	21.56	4	5.39	10.82	0.01	1.5
PLM	1.56	4	0.39	0.78		
error (lm)	67.66	136	0.50			
LT	70.78	6	11.80	14.08	0.01	4.9
PLT	23.15	6	3.86	4.61	0.01	1.4
error (lt)	171.01	204	0.84			
MT	5.65	6	0.94	1.75	0.1	0.2
PMT	1.34	6	0.22	0.41		
error (mt)	109.62	204	0.54			
LMT	26.73	12	2.23	4.48	0.01	1.6
PLMT	14.03	12	1.17	2.35	0.01	0.6
error (lmt)	202.76	408	0.50			

† Significance level.

TABLE C-2. Summary of Analysis of Variance, Experiment II.

Source of variation	SS	df	MS	F	α†	ω², %
P	4.44	1	4.44	5.84	0.05	0.34
L	28.41	2	14.21	18.70	0.01	2.49
M	4.46	2	2.23	2.93	0.1	0.27
T	14.58	3	4.86	6.39	0.01	1.14
S*	0.62	1	0.62	0.82		
PL	0.89	2	0.45	0.59		
PM	0.01	2	0.01	0.01		
PT	1.26	3	0.42	0.55		
PS	2.51	1	2.51	3.30	0.1	0.16
LM	2.04	4	0.51	0.67		
LT	7.74	6	1.29	1.70	0.1	0.29
LS	0.47	2	0.24	0.32		
MT	1.35	6	0.23	0.30		
MS	0.17	2	0.09	0.12		
TS	0.43	3	0.14	0.18		
PLM	0.74	4	0.19	0.25		
PLT	2.07	6	0.35	0.46		
PLS	0.07	2	0.04	0.05		
PMT	1.63	6	0.27	0.36		
PMS	0.02	2	0.01	0.01		
PTS	0.62	3	0.21	0.28		
LMT	3.98	12	0.33	0.43		
LMS	0.32	4	0.08	0.11		
LTS	0.98	6	0.16	0.21		
MTS	0.45	6	0.08	0.11		
PLMT	5.46	12	0.46	0.61		
PLMS	0.19	4	0.05	0.07		
PLTS	3.44	6	0.57	0.75		
PMTS	0.24	6	0.04	0.05		
LMTS	1.76	12	0.15	0.20		
PLMTS	0.91	12	0.08	0.11		
W. cell error	987.6	1,296	0.76			
Total	1,079.86	1,439				4.69

* S: subject group.
† Significance level.

Appendix D
DETAILED PERFORMANCE CURVES, EXPERIMENT 1

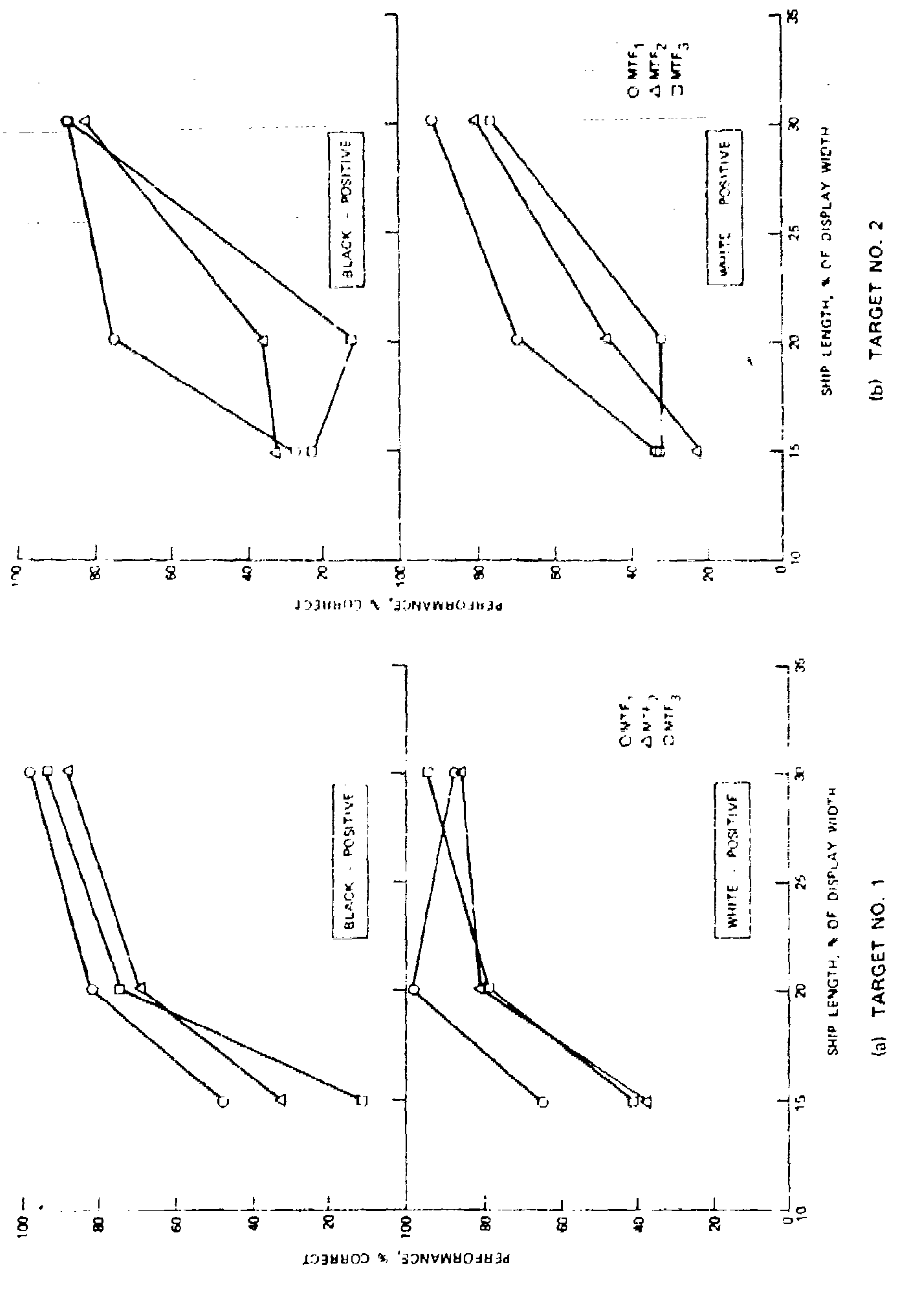


FIGURE D-1. Experiment 1. Performance Versus Image Size and MTF.

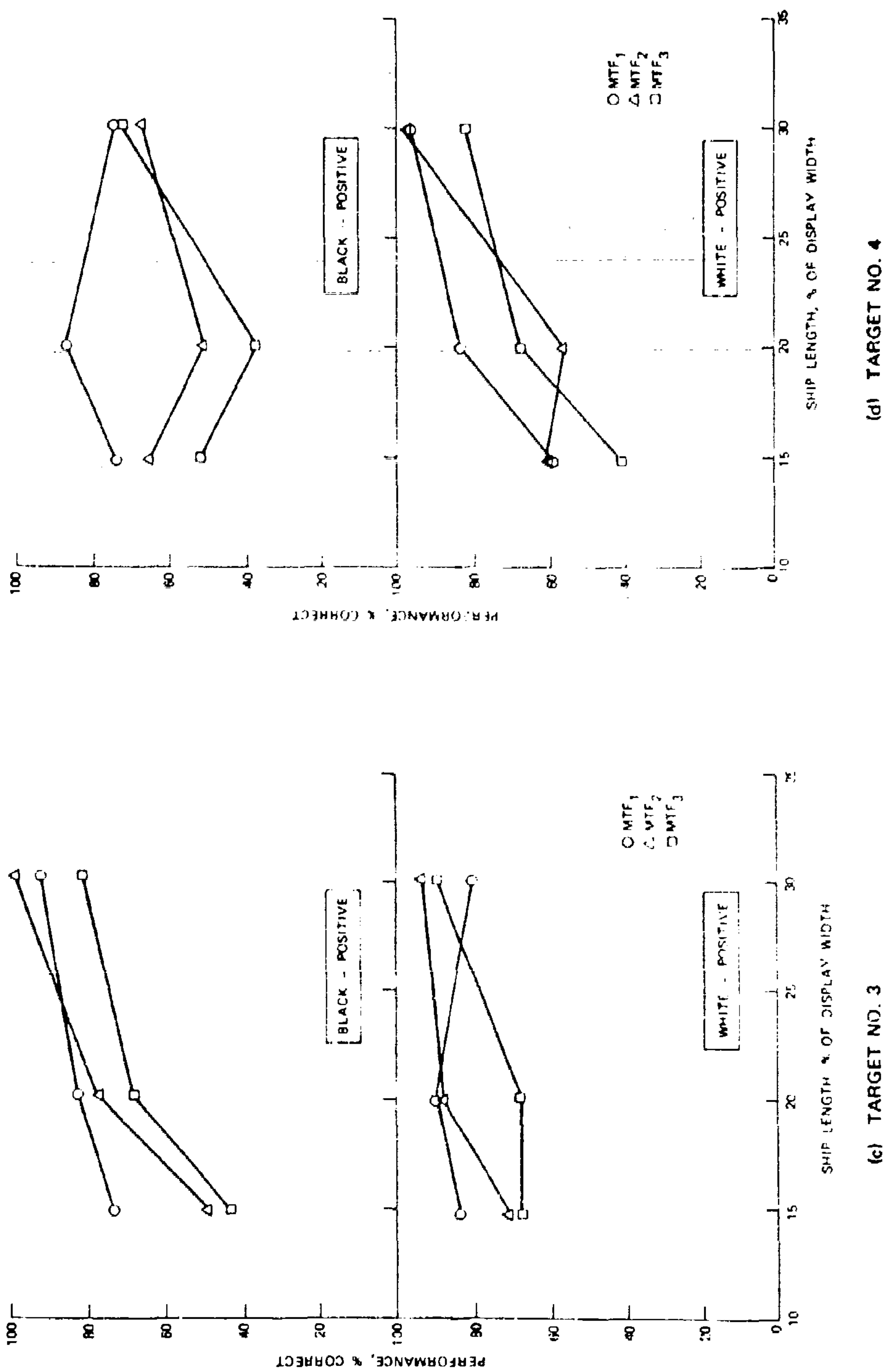
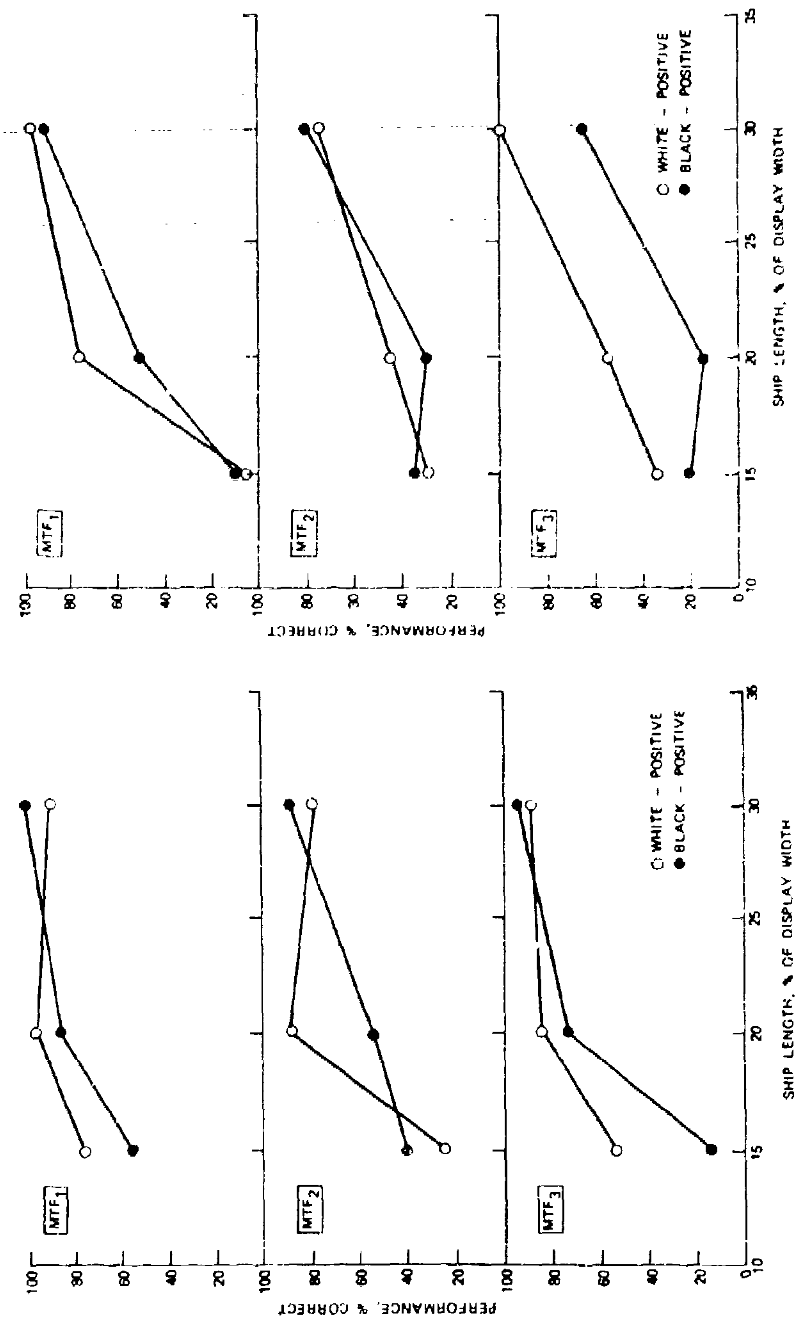


FIGURE D-1. (Contd).

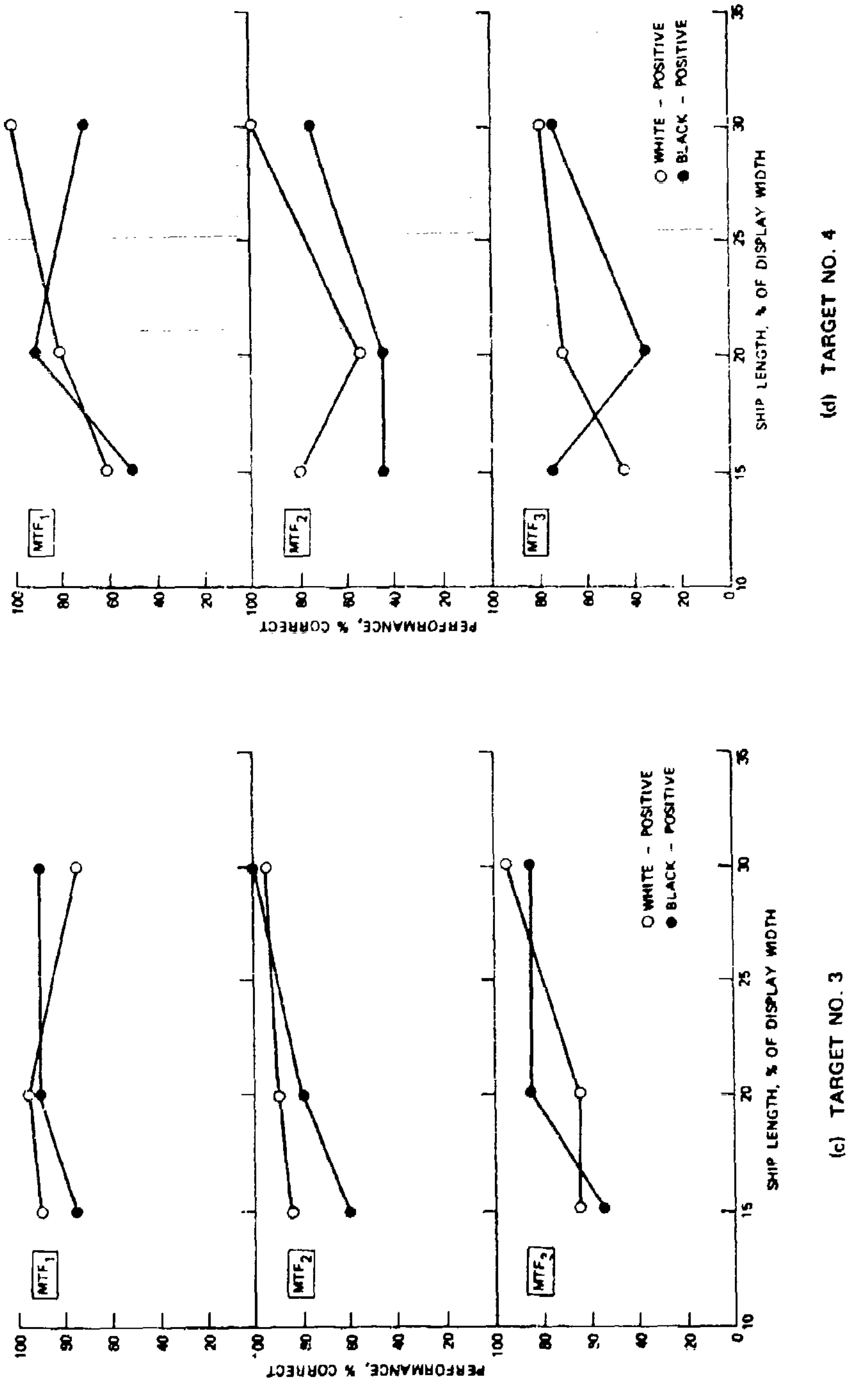
Appendix E
DETAILED PERFORMANCE CURVES, EXPERIMENT II



(a) TARGET NO. 1

(b) TARGET NO. 2

FIGURE E-1. Experiment II. Performance Versus Image Size and MTF.



(c) TARGET NO. 3

(d) TARGET NO. 4

FIGURE E-1. (Contd).

Appendix F
BRIEFING AND INSTRUCTIONS

This experiment is designed to test your ability to identify warships by a television presentation of their silhouettes. Several combinations of range, equipment quality, and atmospheric conditions will be simulated. Photographs of the four ships to be used in this experiment are provided for your reference. These reference photos may be used during the course of the experiment. The photos were taken from the television display and, with the possible exception of contrast, look identical to the real television imagery. Note that there is a fairly large range of conditions, resulting in pretty clear to very fuzzy imagery. Although your reference photos are all approximately the same size, you will see several different sizes during the experiment. All of the ships, however, will be oriented with the stern to the left and the bow to the right, as in the briefing photographs. This should provide for optimal comparison between the TV images and your briefing photos.

The imagery will be presented at 15-second intervals, comprised of a 10-second "look" time and a 5-second pause before the next ship appears. You may make your identification at any time during the 15 seconds. Please respond in a clear, audible voice with the reply number 1, number 2, number 3, or number 4, with the number corresponding with the ship identified.

Although you may use any identification cues you wish, your performance will probably benefit from the following observations. (One) Except for the fuzziest conditions, a distinction can be made between the first two ships and the last two in your briefing photos. The first two ships exhibit a definite break or separation between the forward and rear sections of the superstructure. The shape of the superstructures' images for the last two ships, however, is basically triangular with much less visible irregularity. (Two) Distinguishing ship number 1 from ship number 2 is a bit more difficult. The most apparent difference, even under the most fuzzy conditions, is the relatively larger, more massive stern of ship number 1. (Three) The main difference between number 3 and number 4 is the location of the highest point in their superstructures. The superstructure of number 3 peaks directly amidship. The superstructure of number 4 peaks more toward the forward section of the ship.

Before the actual experiment begins, you will be afforded the opportunity to develop your comparison and identification techniques. There will be two groups of practice trials. In group number 1, you will be given the correct identification as each ship appears on the display. This will take approximately 5 minutes. In the second group of practice trials, which will take about 8 minutes, you are to respond as you will in the main experiment with a clear, audible reply identifying each ship. For your benefit, during the group 2 practice trials, you will be allowed a second look at each ship after the 15-second trial in which you've made your identification. This "second look," during which you will be given the correct choice, will be 5 seconds long and will be followed by another 5-second pause preceding the next trial.

Remember, even though you have a limited time in which to respond, the emphasis is on correct identification and your response time will not be measured. The complete experiment will take about 45 minutes, within which there will be several short rest periods.

Three additional instructions: (One) During the experiment, this buzzer [a buzzer sounds] will sound as each ship appears. (Two) Do not touch the display controls. (Three) Try to keep your forehead next to the positioning bar.

There will be a brief pause now, during which you may ask questions on those points you have not fully understood.

Appendix G

DETAILED PRESENTATION ORDER

Each subject in Experiment I received three sets of trials, referred to as repetition 1, repetition 2, and repetition 3 in that order. Each repetition contained a complete set of trials; i.e., all possible combinations of image size, MTF, and specific target. With three levels of both image size and MTF and four targets, each repetition contained 36 trials. Subjects 1 through 18 saw imagery of black-positive polarity and subjects 19 through 36 saw imagery of white-positive polarity.

Since calibration procedures for the video equipment were somewhat complex, the 36 trials in each repetition were blocked into groups according to MTF. The orders of presentation within each of these nine groups (3 MTFs times 3 repetitions) were then randomized and are given for each group in Table G-1. The orders of presentation of the groups to each subject are given in Table G-2. The only exception to randomization of the block presentation is that the first group of any repetition was not allowed to have the same MTF as the first group of any prior repetition.

The presentation order for the additional trials required by each subject participating in Experiment II were the same as in the first two trials of Experiment I. The subjects who participated in Experiment II were numbers 1, 4, 6, 14, 17, 20, 21, 29, 32, and 35. The presentation order of the practice trials was the same for all subjects and is given in Table G-3.

TABLE G-1. Experiment I, Randomized Order Within Blocks, According to Repetition Number.

TRIAL NO.	BLOCK DESIGNATION								
	REPETITION 1			REPETITION 2			REPETITION 3		
	$1M_1$	$1M_2$	$1M_3$	$2M_1$	$2M_2$	$2M_3$	$3M_1$	$3M_2$	$3M_3$
1	$M_1L_3T_2$	$M_2L_2T_2$	$M_3L_3T_4$	$M_1L_3T_4$	$M_2L_3T_3$	$M_3L_2T_3$	$M_1L_2T_2$	$M_2L_1T_1$	$M_3L_2T_2$
2	$M_1L_2T_3$	$M_2L_2T_3$	$M_3L_2T_3$	$M_1L_2T_4$	$M_2L_2T_3$	$M_3L_1T_4$	$M_1L_1T_2$	$M_2L_1T_4$	$M_3L_2T_1$
3	$M_1L_3T_3$	$M_2L_1T_1$	$M_3L_2T_4$	$M_1L_1T_1$	$M_2L_3T_2$	$M_3L_1T_2$	$M_1L_2T_1$	$M_2L_1T_3$	$M_3L_3T_3$
4	$M_1L_1T_3$	$M_2L_1T_4$	$M_3L_2T_1$	$M_1L_3T_2$	$M_2L_3T_4$	$M_3L_3T_4$	$M_1L_3T_3$	$M_2L_1T_2$	$M_3L_1T_1$
5	$M_1L_3T_4$	$M_2L_3T_4$	$M_3L_3T_1$	$M_1L_2T_1$	$M_2L_3T_1$	$M_3L_2T_4$	$M_1L_2T_4$	$M_2L_3T_1$	$M_3L_3T_1$
6	$M_1L_1T_2$	$M_2L_2T_1$	$M_3L_3T_2$	$M_1L_1T_2$	$M_2L_2T_4$	$M_3L_3T_3$	$M_1L_2T_3$	$M_2L_2T_1$	$M_3L_1T_3$
7	$M_1L_2T_2$	$M_2L_1T_3$	$M_3L_1T_1$	$M_1L_2T_2$	$M_2L_2T_2$	$M_3L_2T_2$	$M_1L_3T_2$	$M_2L_2T_2$	$M_3L_1T_4$
8	$M_1L_1T_4$	$M_2L_3T_1$	$M_3L_1T_2$	$M_1L_3T_1$	$M_2L_1T_4$	$M_3L_3T_2$	$M_1L_3T_4$	$M_2L_3T_2$	$M_3L_1T_2$
9	$M_1L_1T_1$	$M_2L_2T_4$	$M_3L_3T_3$	$M_1L_1T_4$	$M_2L_2T_1$	$M_3L_1T_1$	$M_1L_1T_3$	$M_2L_3T_4$	$M_3L_3T_4$
10	$M_1L_2T_4$	$M_2L_3T_3$	$M_3L_2T_2$	$M_1L_3T_3$	$M_2L_1T_1$	$M_3L_1T_3$	$M_1L_1T_4$	$M_2L_3T_3$	$M_3L_2T_4$
11	$M_1L_2T_1$	$M_2L_3T_2$	$M_3L_1T_3$	$M_1L_2T_3$	$M_2L_1T_3$	$M_3L_3T_1$	$M_1L_1T_1$	$M_2L_2T_4$	$M_3L_3T_2$
12	$M_1L_3T_1$	$M_2L_1T_2$	$M_3L_1T_4$	$M_1L_1T_3$	$M_2L_1T_2$	$M_3L_2T_1$	$M_1L_3T_1$	$M_2L_2T_3$	$M_3L_2T_3$

TABLE G-2. Experiment I, Presentation Order of Blocks.

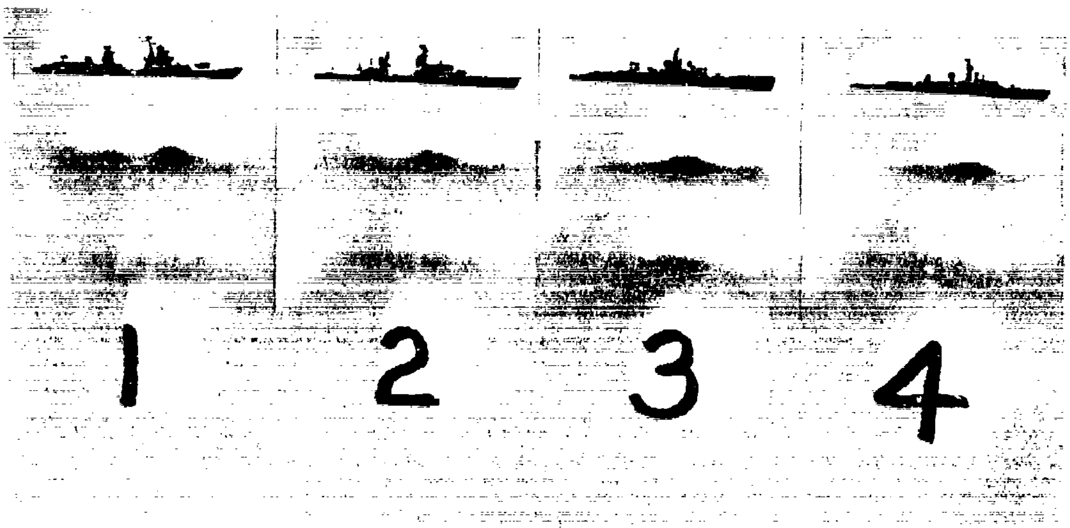
SUBJ NO	REPETITION 1			REPETITION 2			REPETITION 3		
	1ST	2ND	3RD	4TH	5TH	6TH	7TH	8TH	9TH
1&19	$1M_1$	$1M_2$	$1M_3$	$2M_3$	$2M_1$	$2M_2$	$3M_2$	$3M_1$	$3M_3$
2&20	$1M_1$	$1M_3$	$1M_2$	$2M_2$	$2M_3$	$2M_1$	$3M_3$	$3M_1$	$3M_2$
3&21	$1M_1$	$1M_2$	$1M_3$	$2M_3$	$2M_1$	$2M_2$	$3M_2$	$3M_3$	$3M_1$
4&22	$1M_2$	$1M_3$	$1M_1$	$2M_1$	$2M_3$	$2M_2$	$3M_3$	$3M_1$	$3M_2$
5&23	$1M_3$	$1M_2$	$1M_1$	$2M_2$	$2M_3$	$2M_1$	$3M_1$	$3M_3$	$3M_2$
6&24	$1M_1$	$1M_3$	$1M_2$	$2M_2$	$2M_1$	$2M_3$	$3M_3$	$3M_1$	$3M_2$
7&25	$1M_3$	$1M_1$	$1M_2$	$2M_1$	$2M_2$	$2M_3$	$3M_2$	$3M_3$	$3M_1$
8&26	$1M_1$	$1M_3$	$1M_2$	$2M_3$	$2M_2$	$2M_1$	$3M_2$	$3M_3$	$3M_1$
9&27	$1M_1$	$1M_3$	$1M_2$	$2M_3$	$2M_2$	$2M_1$	$3M_2$	$3M_1$	$3M_3$
10&28	$1M_2$	$1M_3$	$1M_1$	$2M_3$	$2M_2$	$2M_1$	$3M_1$	$3M_3$	$3M_2$
11&29	$1M_2$	$1M_3$	$1M_1$	$2M_1$	$2M_2$	$2M_3$	$3M_3$	$3M_1$	$3M_2$
12&30	$1M_1$	$1M_3$	$1M_2$	$2M_2$	$2M_1$	$2M_3$	$3M_3$	$3M_2$	$3M_1$
13&31	$1M_2$	$1M_3$	$1M_1$	$2M_3$	$2M_1$	$2M_2$	$3M_1$	$3M_3$	$3M_2$
14&32	$1M_3$	$1M_2$	$1M_1$	$2M_1$	$2M_2$	$2M_3$	$3M_2$	$3M_3$	$3M_1$
15&33	$1M_2$	$1M_3$	$1M_1$	$2M_1$	$2M_3$	$2M_2$	$3M_3$	$3M_2$	$3M_1$
16&34	$1M_3$	$1M_2$	$1M_1$	$2M_2$	$2M_1$	$2M_3$	$3M_1$	$3M_3$	$3M_2$
17&35	$1M_3$	$1M_1$	$1M_2$	$2M_2$	$2M_3$	$2M_1$	$3M_1$	$3M_3$	$3M_2$
18&36	$1M_1$	$1M_2$	$1M_3$	$2M_3$	$2M_2$	$2M_1$	$3M_2$	$3M_1$	$3M_3$

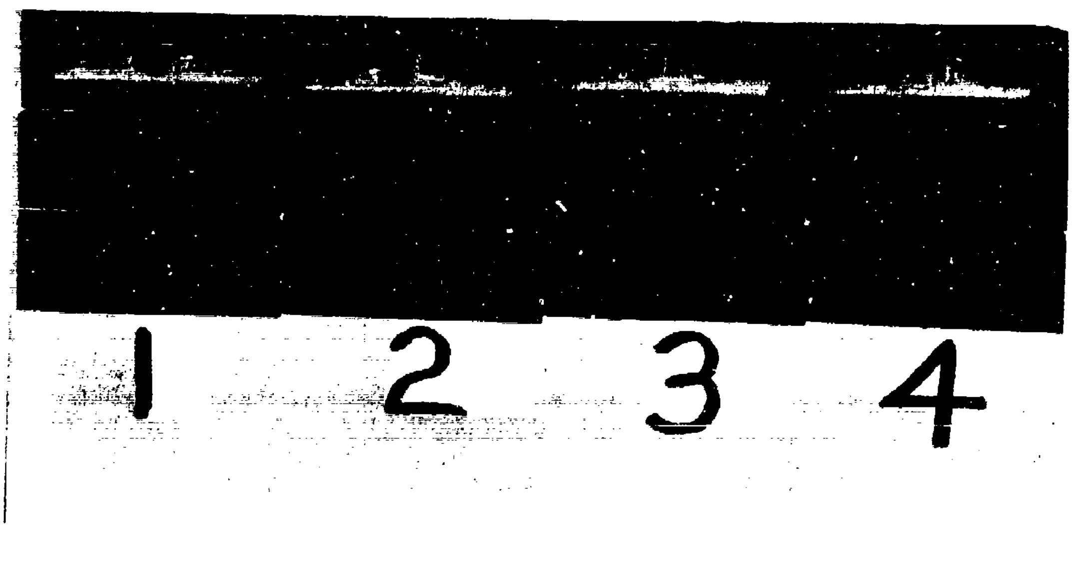
TABLE G-3. Order of Practice Trials (Experiment I).

GROUP 1			GROUP 2		
TRIAL NO.	CONDITION		TRIAL NO	CONDITION	
1	M_1	L_2T_2	19	M_1	L_2T_4
2	M_1	L_1T_1	20	M_1	L_3T_2
3	M_1	L_1T_4	21	M_1	L_1T_3
4	M_1	L_3T_1	22	M_1	L_2T_1
5	M_1	L_3T_3	23	M_1	L_1T_2
6	M_1	L_2T_3	24	M_1	L_3T_4
7	M_2	L_3T_3	25	M_2	L_2T_3
8	M_2	L_1T_1	26	M_2	L_2T_1
9	M_2	L_2T_4	27	M_2	L_1T_4
10	M_2	L_2T_2	28	M_2	L_1T_2
11	M_2	L_1T_3	29	M_2	L_3T_4
12	M_2	L_3T_2	30	M_2	L_3T_1
13	M_3	L_2T_2	31	M_3	L_2T_3
14	M_3	L_1T_2	32	M_3	L_3T_3
15	M_3	L_3T_1	33	M_3	L_1T_1
16	M_3	L_1T_3	34	M_3	L_2T_1
17	M_3	L_3T_4	35	M_3	L_1T_4
18	M_3	L_2T[illegible]	36	M_3	L_3T_2

Appendix H

BREIFING CARDS, REFERENCE PHOTOGRAPHS





Appendix I

IMAGERY CHARACTERIZATION—ADDITIONAL COMMENTS

A comprehensive description of the "resolving" capabilities of a contrast-limited imaging system should be given by its optical transfer function or its line spread response curve. However, the only information lost by employing solely an MTF curve--which is easier to measure--is the effect of any phase distortion as a function of spatial frequency. An examination of test imagery generated by the television system, degraded as it was during the experiment, revealed that any phase shifts--which for the television system would take place in the video tape recorder--were imperceptible. Therefore, only the MTF of the system was measured.

Actually, owing to the nonavailability of sine wave bar patterns, the square-wave responses of the system's components were measured. The system had a reasonably linear response over the ranges of inputs and outputs encountered in the experiment. Therefore, a satisfactorily accurate determination of MTF (sine-wave response) was made by calculating the sine-wave responses of the system's components from the measured square-wave responses. These were then multiplied together to get the system's sine-wave response. This procedure was followed to obtain each of the three curves in Figure 5.

To check this procedure, the system's square-wave response curves were calculated from the component-derived sine-wave response curves for the system and compared with directly-measured square-wave response curves for the system. This comparison revealed insignificant differences.

For the component-derived calculations, the camera inputs and outputs were measured at five spatial frequencies between 3 and 26.5 cycles per display width. The camera inputs were measured with a spot-telephotometer and its outputs were measured with an oscilloscope. Inputs to both the video tape recorder and the TV monitor were provided, at six frequencies between 0.5 and 4.2 MHz, by an electronic TV test pattern generator. The tape recorder was played back and the video signals were measured with an oscilloscope, while the TV monitor output was measured with a slit-masked microphotometer. The direct measurement of the system square-wave responses involved photometric measurements of the camera inputs, while videotaping, and the TV monitor outputs, while playing back the videotaped bar patterns. The system square-wave responses, calculated from component-derived data, are given in Figure I-1.

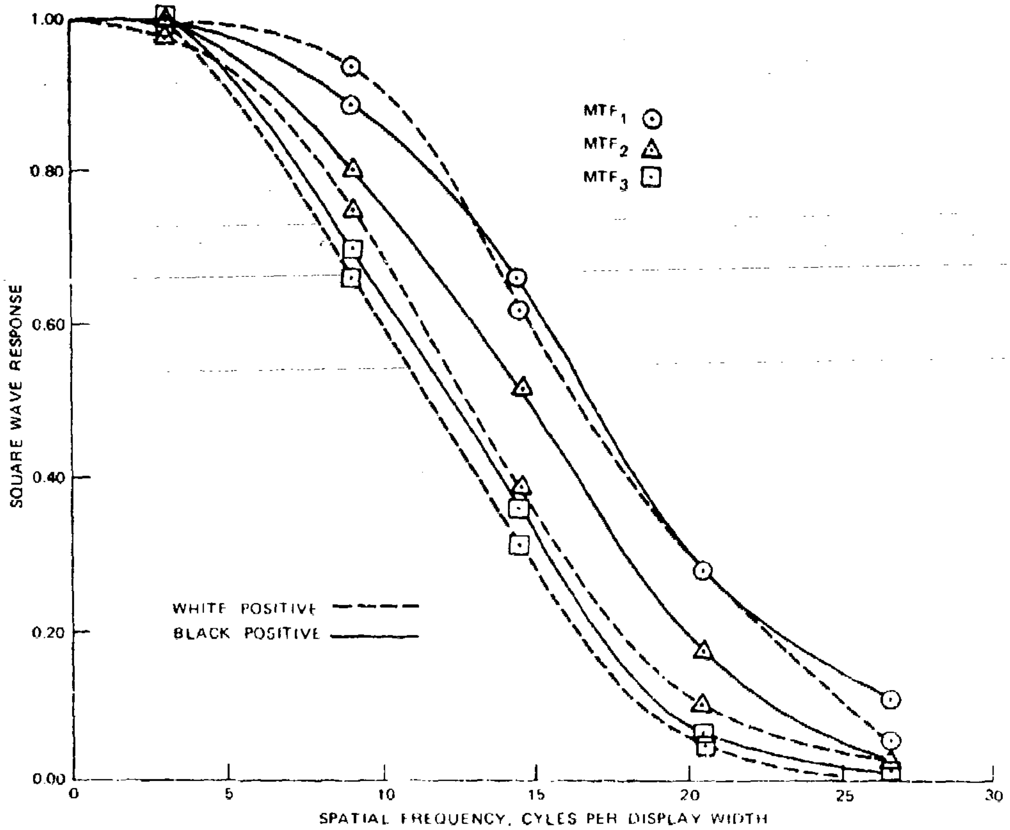


FIGURE I-1. System Square-Wave Response (Calculated Via Component Square-Wave Response and Sine-Wave/Square-Wave Response Transformations).

The MTF of the system was controlled with the focus adjustment of the electron beam in the TV camera tube, a standard 1 1/2-inch vidicon. This method of MTF control did have some rather inconveniencing disadvantages, which were discovered during the taping of the ship imagery. The focus control on the camera control unit adjusts the potential on one of a series of grids in the camera tube. However, the beam's focus, as well as other tube parameters that may depend mainly on the potential of a particular grid, really are influenced by the total array of different potentials the beam passes through. In the present case, for example, the blanking level was partially a function of the focus knob setting. Another inconvenience was the interaction between the magnetic deflection fields and the electrostatic/magnetic focusing fields. When the beam was defocused to produce the MTF curves of Figure 5, the picture being displayed would rotate up to 12 degrees. The camera had to be tilted to compensate for this.

For reasons not understood, the video equipment produced higher MTF curves for black-positive imagery than for white-positive imagery. This effect is also shown in Figure 1-1. This effect was not compensated for, since it was not known until after the experiment had been completed. Compensation for this counfoundedness should act in such a way as to increase, rather than decrease, the significance of the experimental results.

Fortunately, both component and total system signal transfer functions were measured. The video tape recorder input level control was not properly readjusted prior to recording the black-positive gray scales, which left this section of the tape useless for the determination of the black-positive signal transfer function. However, with data taken from a camera/monitor configuration, the individual component data, and the assumption that the video tape recorder SiTF was not a function of polarity, it was possible to calculate the black-positive SiTF for the system, which is plotted in Figure 1-2. A best least-squares power curve fit to the white-positive SiTF data for the system was used in these calculations. This curve also is shown in Figure 1-2 along with the white-positive data points. It should be noted that, over the region of input levels containing the data points, a best least-squares linear fit to the data was as good as the power curve fit shown.

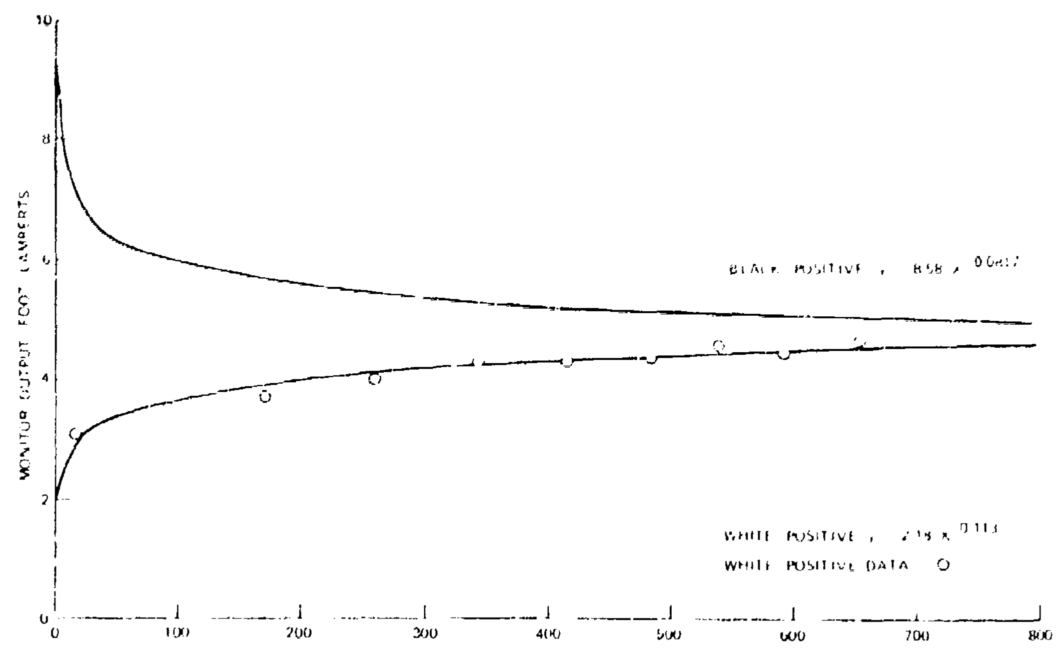


FIGURE 1-2. System Signal Transfer Function With Focused Camera and All Other Parameters as Were Used in the Experiments. (Black-positive data was lost on the videotape, necessitating calculation of the black-positive curve from signal transfer data of the system's components. Curve fit to data was made with $y = ax^{\gamma}$.)

It was mentioned in the section on image size that, strictly speaking, image size was also a function of MTF and SiTF. As a measure of the size change due to changes in MTF, a measurement of ship image length was made on the face of a TV monitor. The active display width was 7.2 inches. Table I-1 shows the results of this comparison, where the entries are shown both as absolute measurements and as proportions of the active display width.

TABLE I-1. Displayed Ship Image Lengths.

Target number	L_1 (30%)			L_2 (20%)			L_3 (15%)		
	MTF_1	MTF_2	MTF_3	MTF_1	MTF_2	MTF_3	MTF_1	MTF_2	MTF_3
1, 2, and 3	2.2[a] (31)[b]	2.3 (32)	2.5 (35)	1.6 (22)	1.6 (22)	1.8 (25)	1.1 (15)	1.1 (15)	1.2 (17)
4	2.1 (29)	2.2 (31)	2.4 (33)	1.4 (19)	1.4 (19)	1.6 (22)	1.0 (14)	1.0 (14)	1.1 (15)

Note: Accuracy of measurements limited by fuzzy edges of target images.

[a] Top entry is measured ship image length in inches.
[b] Bottom entry is ship image length expressed as percent of display width.

Although the SiTF was not an independent variable, separate from polarity, it is an important parameter to document, since, as mentioned before, image size can also be a function of the SiTF. The effect that the SiTF has on apparent image size is, in general, confounded with polarity. However, since the system used in this experiment had an approximately linear response, these two effects would be independent of one another. The effect that a nonlinear SiTF has on image size is rarely considered to be important, if considered at all, because imaging systems are usually designed with relatively good MTFs and, hence, spatially small luminance transition regions defining target edges. However, even with a high-quality system other parameters such as atmospheric conditions can cause large transition regions. In these cases, a superlinear SiTF will "compress the blacks" to make dark targets appear larger and light ones smaller, and a sublinear SiTF will "compress the whites" and result in the opposite effect.

Appendix J

VARIABLE LEVEL SELECTION

The particular values of image size and MTF used in this study were chosen by means of a pilot experiment and a visual examination of videotaped FLIR imagery. The first step involved a subjective analysis of videotaped warship imagery, taken by A-6C TRIM-equipped aircraft in the Mediterranean. For the range of image quality on these videotapes, the analysis determined that, with the level of briefing to be given the subjects, a high correct identification rate could be attained when the ship image lengths were between 15 and 30% of the horizontal display width. Therefore, image lengths for the study were chosen to be 15, 20, and 30% of the display width.

The second step consisted of a pilot experiment in which MTF and display contrast were varied until the subjects were performing with correct identification rates from 25% (chance level) to almost 100%. By this procedure, the MTF curves in Figure 5 were chosen and the large-target/background contrast was chosen to be 40%. For the chosen image sizes, very little to no internal detail was visible in the A-6C TRIM-generated target images. Therefore, only silhouettes were produced in the TV imagery.

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